

**13th International Meeting
on
Low Frequency Noise and Vibration and its Control
Tokyo, JAPAN 21-23 October 2008**

**Activity report of “Working Group on evaluation of
habitability to low frequency noise and vibration”,
Architectural Institute of Japan**

Satoshi SHINDO ¹, Takashige ISHIKAWA ² and Sunao KUNIMATSU ³

¹Department of Architecture, Collage of Eng., Hosei University,
Kajino-cho 3-7-2, Koganei, Tokyo, 184-8584, JAPAN.
E-mail: satoshi.sindo.az@k.hosei.ac.jp

² Department of Housing and Architecture, Faculty of Home
Economics, Japan Women's University,
Mejirodai 2-8-1, Bunkyo, Tokyo, 112-8681, JAPAN.
E-mail: ishikawa@fc.jwu.ac.jp

³Institute for Geo-Resources and Environment, National Institute of
Advanced Industrial Science and Technology (AIST),
Higashi 1-1-1, Tsukuba, Ibaraki, 305-8567, Japan.
E-mail: s.kunimatsu@aist.go.jp

Summary

The committee on environmental vibration, Architectural Institute of Japan installed the working group on evaluation of habitability for low frequency noise and vibration in 2006 to correspond to the low frequency noise and vibration problem about building occurred in urban areas in recent years. The WG member consists of a variety of specialists, such as not only the architectural field but also ergonomics, mechanical engineering, civil engineering, acoustics, etc. The WG is functioning as a place of information exchange with other academic societies. In this paper, the activity reports from 2006 to 2007 and the main activities in the 2008 fiscal year about the collection of case research for building design and the outline of installation manual for home equipments, namely outdoor unit of room air-conditioning equipment etc. are described.

1 Introduction

Recently, it is said that the back ground noise has decreased because the sound insulating properties of the room have improved remarkably by the increase of airtight

structure. In consequence, the noise of low level that did not become a problem up to now shows the tendency toward the surfacing. In general, high sound insulating properties can be expected in the high frequency noise, while the low frequency noise transmits easily to the room. Therefore, the low frequency noise which has been not noticed because of existence of high frequency noise (masking) is perceived by the inhabitant. Furthermore, in the house crowd area of the urban region, the influence to the adjacent house is feared even the noise to be generated from the low-power equipment due to the narrow space between the buildings.

For such occasion, the committee on environmental vibration, Architectural Institute of Japan installed the working group on evaluation of habitability in low frequency noise and vibration in 2006 to deal with low frequency noise problems about building that occur in urban areas in recent years. The WG member consists of various specialists of not only the architectural research field but also ergonomics, mechanical engineering, civil engineering, acoustics, etc. The WG is functioning as a place of information exchange with other academic societies. In this paper, the activity reports from 2006 to 2007 are described in the first half, and the main activities in the 2008 fiscal year about the collection of case research for building design and the outline of installation manual for home equipments are described in the second half.

2 Activity report of WG

The WG set up the following four SWG, and findings, the measurement and the experimental data etc. in past were collected in each SWG.

- 1) SWG1: Source Understanding of the noise characteristic of equipment with possibility to generate low frequency noise
- 2) SWG2: Anec-data Collection of actual survey examples of the low frequency noise
- 3) SWG3: Evaluation Collection of the past findings about evaluation for low frequency noise and the recognition of the problems
- 4) SWG4: Propagation Consideration of the propagation path in air and in solid and the examination of the numerical simulation to elucidate the propagation properties

In this paper, three items of 1) to 3) described above are reported.

2.1 Source

Home equipments were taken up as object sources from various sources which generate the low frequency noise, such as boiler, freezing machine, air blower, vibrating screen, etc, in consideration of the following two points from the viewpoint of the approach from an architectural field.

- 1) To have the possibility generated the low frequency noise in the general residential area as noise source.
- 2) To be used in a general house.

Specifically they are the outdoor unit of room air-conditioners, the heat pump water heater, alias “Eco-cute”, and the washing machine with the heat pump dryer. The following items are brief summary about each noise sources obtained from the past discussion.

Outdoor unit of room air-conditioners

- It generally has a frequency component of 100Hz (200Hz) or 120Hz (240Hz).
- In comparison with the noise source characteristic at the one equipment operation, the characteristic at the simultaneous operation of multiple equipments shows the different characteristic.
The influence on the adjacent house changes by the installation position. For example, though the outdoor unit is often installed in the position of the north side of the house, it is located in the south side with many openings for the north side neighboring house.
- At present, there is not the guideline about the low frequency noise to the maker, and it is left to the self-imposed restraint of the maker.
- The case that had the problem of the low frequency noise in the case of the condition powered down in the operation rather than the steady operation condition was reported.
- To reduce the low frequency noise, measures of output adjustment of equipment and vibration preventing in building are taken.
- In spite of the low frequency noise level equal to or less than the threshold level, the case that the lodgment of a complaint produces from inhabitants is reported from results of field measurement survey.

Heat pump water heater, alias “Eco-cute”

- Even if the ratings noise was satisfied with the maker specifications at the operation, the problem of low frequency noise to neighboring inhabitants is feared to use the electricity of the late-night time that it is low charge than the charge of daytime, but background noise is low in the time.
- It is very likely that the problem occurs in the winter season with much volume of necessary hot water supply in comparison with the summer.
- Because the increase of demand for Eco-cute is expected from now on, it is necessary to take it up as a urgent research issue in the WG.

Heat pump dryer

- Because it put a compressor in the main body of indoor machinery from the structure of product, it corresponds to setting up the noise source indoors.
- However, because the operating time of the compressor is about 1 to 1.5 hours at the time of drying, it is a shorter time than it of the outdoor unit.

The following points are future research issues about the noise source.

- 1) Making of database of physical characteristic of low frequency noise source (such as frequency characteristic in 1/3 oct., etc.).

- 2) Understanding of frequency characteristic of the noise at the time of the simultaneous operation of multiple equipments.
- 3) Comparison of the characteristic of the noise by the various kinds of operation condition.
- 4) Examination of effective measures against low frequency noise from architectural side.

2.2 Anec-data

We are collecting the actual measured data from published reports and personal data measured by committee member, and are examining those data. Yamada who is one of the WG members measured quite a lot of kinds of noise sources and he opened the data^[1] to the WG. In the SWG1, the characteristic of each noise source is investigated with those data. Some examples of the measured data in the room by various sources were shown in Fig. 2. Here, the data of freezer, blower, and boiler shown in Fig.2 are the data measured in the condition that the window was opened.

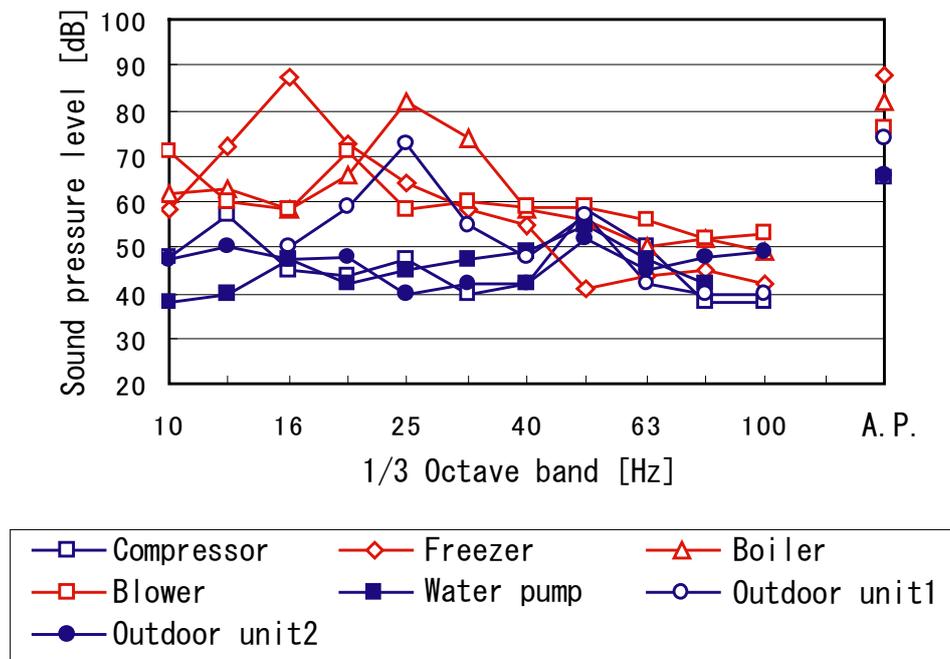


Fig.2 Measurement example in the room.

In addition, Ochiai^[2] examined the sound level difference in the inside and the outside of the building by using various kinds of sash, and indicated that the differences were different with the kinds of the structure of house and the sash. Fig. 3 shows examples of the measured sound level difference by various kinds of sash.

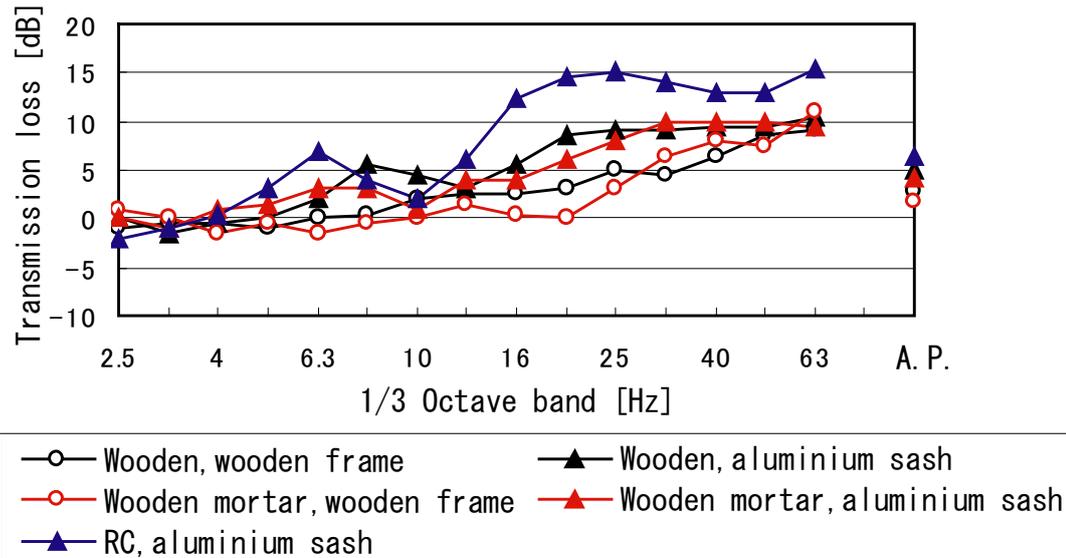


Fig. 3 Examples of the measured sound level difference by various kinds of sash.

Moreover, the possibility of generation of remarkable stationary wave which come of the dimension of room is suggested as a unique problem of the low frequency noise. The collection of further actual measured data and the examination of the measuring method will seem to be need in future.

Besides, the information for the complaint for the physical influence which occupies half the number of all complaints is collected in WG. Kunimatsu et al. [3] [4] analyzed fittings such as sliding doors by using Distinct Element Method (DEM). The sine wave and the recorded measurement sound wave form (blast sound) were input into the modeled sliding doors while changing sound pressure in DEM analysis. The rattling condition was arranged at the number of times of contact with the top rail of sliding doors and head jamb in the numerical results. It was reported the results were almost corresponding to the rattling threshold of fittings from actual measurement shown by Ministry of the Environment [5]. Moreover, Ochiai [6] conducted the experiment that increased the number of object fittings such as the glass door, the sliding door, the shutter, the sliding door with wall paper and the paper door as wood furniture, and the aluminum sash and the steel sash as the metallic furniture. As a result, he reported that the rattling strongly come under the influence of the installation condition of fitting in particular though the rattling was affected by predominant frequency of low frequency noise, type and weight of fittings and installation condition of fitting about the factor related to the rattling.

The following points were discussed so far about anecdotal data.

- The generation of the stationary wave having the predominant frequency of about 50Hz is feared in the room of the area from six to eight pieces of tatami mats.
- There are actual measurement cases that the distinction of a phenomenon by the low frequency noise or a phenomenon by the vibration is difficult.

- It is very difficult to evaluate rattling of fittings systematically because the characteristic changes by shape, weight, and installation condition etc. of the fittings.

The following points are coming research issues about the measurement.

- 1) Examination of intended frequency range.
- 2) Verification of the influence on object such as rattling of fittings.
- 3) Verification of occurrence of standing wave by the dimensions and the shape of the room.
- 4) Examination of distinction of a phenomenon by the low frequency noise or a phenomenon by the vibration and those compound influence.

2.3 Evaluation

Many researches^[7] on the human body response have been performed in past times, and “Handbook to Deal with Low Frequency Noise”^[8] was published by the Ministry of the Environment. However, it is pointed out that the examination about the problems of individual variation in human sense and a sound field having multi frequency component of the noise which generated from multiple sound sources etc. is necessary to research in the future.

The following points are coming research issues about the evaluation.

- 1) Examination of individual variation.
- 2) Examination of the influence of exposure for a long time.
- 3) Examination of the change in audibility by the simultaneous exposure of usual sound and low frequency noise.
- 4) Consideration of low frequency sound pressure distribution in room such as stationary wave.
- 5) Examination of fluctuation such as beat by multiple sound sources.

3 The proposal from WG such as the report of design case and the installation manual of the equipment

As the study on the low frequency noise goes ahead in the sound field and the ergonomics field than architectural field, it is thought that it is necessary to perform collection of useful findings based on cooperation with the other academic societies. However, the examination of the future findings is necessary because the research for the low frequency noise is still on the way in the related academic societies. It is suggested to have to examine the improvement of the guideline etc. based on the latest findings after having verified the effectiveness of them. Then, from the viewpoint of architectural field, the following research items were arranged in a flow chart as follows.

3.1 Viewpoint from architectural field

Though the report of cases for the measures about low frequency noise was published by the Ministry of the Environment, the measures cases that was examined “after” the problem occurred and a manual of the measurement method to use for a purpose of the understanding of the actual situation at the site where the complaint occurred are shown in it. On the other hand, from a viewpoint of the architectural field, it is demanded to predict it “before” the problem occurs, so that the complaint concerning the low frequency noise does not occur from the user of the building. The architect needs a convenient practicable measurement method and a prediction method, and the unified, plain performance indication for building.

3.2 Examination item and flow chart

The items which should be examined in WG are shown below as a flow chart.

Layout planning

- Installation position, layout, and operation condition of source.

Estimation

[Characteristic of source]

- Accumulation of source data (making of data base).
- Understanding of frequency characteristic, sound pressure level and the level fluctuation (including beat etc) in source.

[Source to outside wall of house]

- Propagation characteristic.

[Outside wall of house to indoor]

- Transmission loss and its frequency characteristic.
- Difference by the condition of the house (such as the kinds of the sash, etc.).

[Indoor]

- Position, number, direction of opening such as window and the direction of the sound source and the distance from sound source (including influence of phase, etc.).
- Prediction of sound pressure level in indoor.
- Influence of stationary wave, sound pressure distribution (a difference by the opening and shutting of a window or the indoor door).
- Propagation of solid-borne sound in case that source is installed in the building.

Influence and evaluation

- Reference of publication of the Ministry of the Environment.
- Determination of the case caused by low frequency noise, the case caused by a factor except low frequency noise and the case caused by the both influence.

Measures

- Understanding of the occurrence condition and the occurrence mechanism.
- Examination of measures method.
- Collection of measures cases.
- Setting of desired value of measures.

Design flow

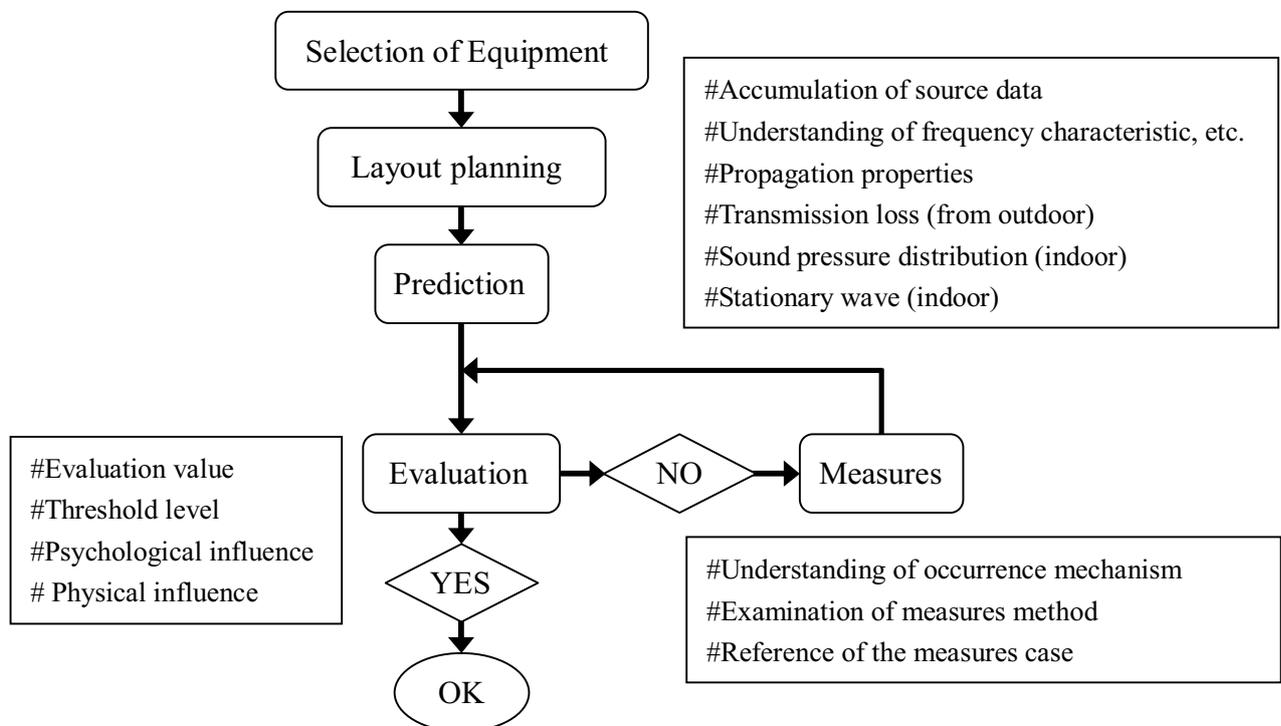


Fig.3 Design flow

4 Conclusions

After the examination of the above-mentioned items, the publication of “Design cases” as tentative name is planned through the panel discussion of the Architectural Institute of Japan as a final target. The activity in AIJ is scheduled to be continued for the solution of the low frequency noise problem.

Acknowledgement

We would like to express our special thanks to the following WG member.

Enamito, A	Mechanical System Laboratory, Toshiba Corporation
Fujisawa, Y	Technical Research Institute , Obayashi Corporation
Kurakata, K	National Institute of Advanced Industrial Science and Technology
Maruta, Y	Ebara Research Co., Ltd
Masuda, I	Japan transportation consultants, Inc.
Matsumoto, Y	Dept. of Civil and Env. Eng., Saitama Univ.
Ochiai, H	Kobayashi Institute of Physical Research
Shioda, M	Dept. of Architecture, Kogakuin Univ.
Uchida, H	Research Institute of Technology, Tobishima Corporation
Yamada, S	Open Univ.
Yokoyama, Y	Dept. of Architecture and Building Eng., Tokyo Institute of Technology

References

- [1] S. Yamada, The document submitted to WG. The data which were collected personally for a measurement period of 1980-2003.
- [2] H. Ochiai, "The state of the art of the infra and low frequency noise problem in Japan", Proceedings of Inter-Noise 2001, 1495-1498 (2001).
- [3] S. Kunimatsu, et al, "DEM analysis on the Response of Building Fittings against low frequency sound – Sliding door response against pure tone -", J. of INCE/J, 17 (6), 36-43 (1993).
- [4] S. Kunimatsu, et al, "DEM analysis on the response of building fittings against low frequency sound – Sliding door response against blast sound –" (in Japanese with English abstract), J. of INCE/J, 18 (3), 47-52 (1994).
- [5] Ministry of the Environment,
- [6] H. Ochiai et al, "On the threshold level of rating fittings due to low frequency sound pressure level" (in Japanese with English abstract), J. of INCE/J, 26 (2), 120-128 (2002).
- [7] Ministry of the Environment, Investigative report for low frequency noise (in Japanese), (1978).
- [8] Ministry of the Environment, Handbook to Deal with Low Frequency Noise (in Japanese), (2004).